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Recent Progress in Toner Technology



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ii—Recent Progress in Toner Technology

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Toner Charge Instability

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Abstract

Toner triboelectric charge can be affected by a variety of intrinsic and extrinsic factors, and production and maintenance of a stable charge requires a balancing or minimization of many complex interactions. In this review, major stability factors are discussed and illustrated using actual experimental data coupled with a simple theoretical model. Throughout, the review promotes a holistic approach in order to reinforce the view that toner charge stability is not merely a toner issue.

1. Introduction

In conventional xerography, a latent electrostatic image is developed by triboelectrically-charged toner particles, and xerographic development (to a first order) is an inverse function of toner charge level.¹ From a toner viewpoint, then, triboelectric charge—its polarity, magnitude and stability—is a critical property, and the creation and maintenance of a functional charge value is a major materials design challenge.

Since toner charge is controlled by many intrinsic and extrinsic factors, absolute charge stability is effectively an unattainable goal, and a degree of charge variability must be assumed for any commercial xerographic product. Now, in practical xerographic copiers and printers, variations in toner charge can be compensated for via closed-loop control of other factors that affect development—for example, the electrostatic image potential—but such control schemes add the expense and complexity of image density sensors, electrostatic voltage sensors, environmental temperature/RH sensors, etc.²⁻⁴ For robust simplicity, therefore, toner charge stability remains as an important ultimate design goal.

However, besides the problems outlined thus far, there are important additional toner design limits imposed by the functional requirements of the post-development subsystems, namely the transfer, cleaning and fusing subsystems. For example, toner adhesion and flow properties affect transfer and cleaning performance, and toner rheological and surface-chemical properties are important factors for efficient fusing. As a result, optimum performance in xerographic development is frequently achieved via incorporation of external and/or internal additives (e.g., flow aids, waxes, etc.) into the overall toner design, and unfortunately these additives may also affect toner charge level and stability. Furthermore, since toner triboelectric charge is generated by contacts with other charging surfaces—carrier beads in two-component xerography; donor roll surface and metering blade or roll for single-component xerography—then the quality and stability of these non-toner

surfaces must also be considered in any overall strategy for toner triboelectric charge stability.

Finally, all of the charging interactions listed thus far can also be affected by ambient environmental conditions, since triboelectric charging is especially sensitive to water vapor relative humidity.

All in all, then, triboelectric charge stability is a wide-ranging topic involving many potential complex interactions. To illustrate some of the major controlling factors for charge variability, the following discussion is based on “lessons” from experimental data, with a theoretical model for triboelectric charging being used as an overall conceptual framework.

2. Triboelectric Charging

2.1 Parametric Charging Equation

For a two-component xerographic developer, the toner charge-to-mass ratio, q/m , generated by mixing with carrier beads, can be related to the toner-to-carrier weight concentration, C , by:

$$q/m = [A_0 / (C + C_0)] \cdot [1 - \exp \{-\gamma \cdot t\}] \quad (1)$$

where A_0 and C_0 are characteristic parameters for any particular toner/carrier combination, t is the mixing time and γ is the effective rate constant for the charging process. Now, all of the parameters in Eq. 1 contain contributions from the controlling physics and chemistry of triboelectric charging, and the impact of these contributions on charge stability will next be discussed sequentially in the following sections, in order of increasing complexity.

2.2 Charge Generation

The second term in Eq. 1 is a simple saturating exponential function, and is a functional form typically seen when a simple, additive-free toner is mixed with carrier beads. For this process, the effective rate constant⁵ is:

$$\gamma = \gamma' (C + C_0) \quad (2)$$

where γ' is a direct function of the frequency of toner/carrier mixing contacts.

Thus, for any particular mixing time, a range of q/m values can be achieved simply via an appropriate choice of mixing intensity, and this charging/mixing response is commonly seen in actual mixing experiments.⁷ From a charge stability viewpoint, of course, this mixing intensity effect is a potential source of variability in q/m , and should therefore be avoided. Clearly, an effective strategy would be to set the mixing intensity at a level high enough to